December 26, 1944

Technical Paper No. 104

FOREST PLANTING ON STRIP-MINED COAL LANDS WITH SPECIAL REFERENCE TO OHIO

By

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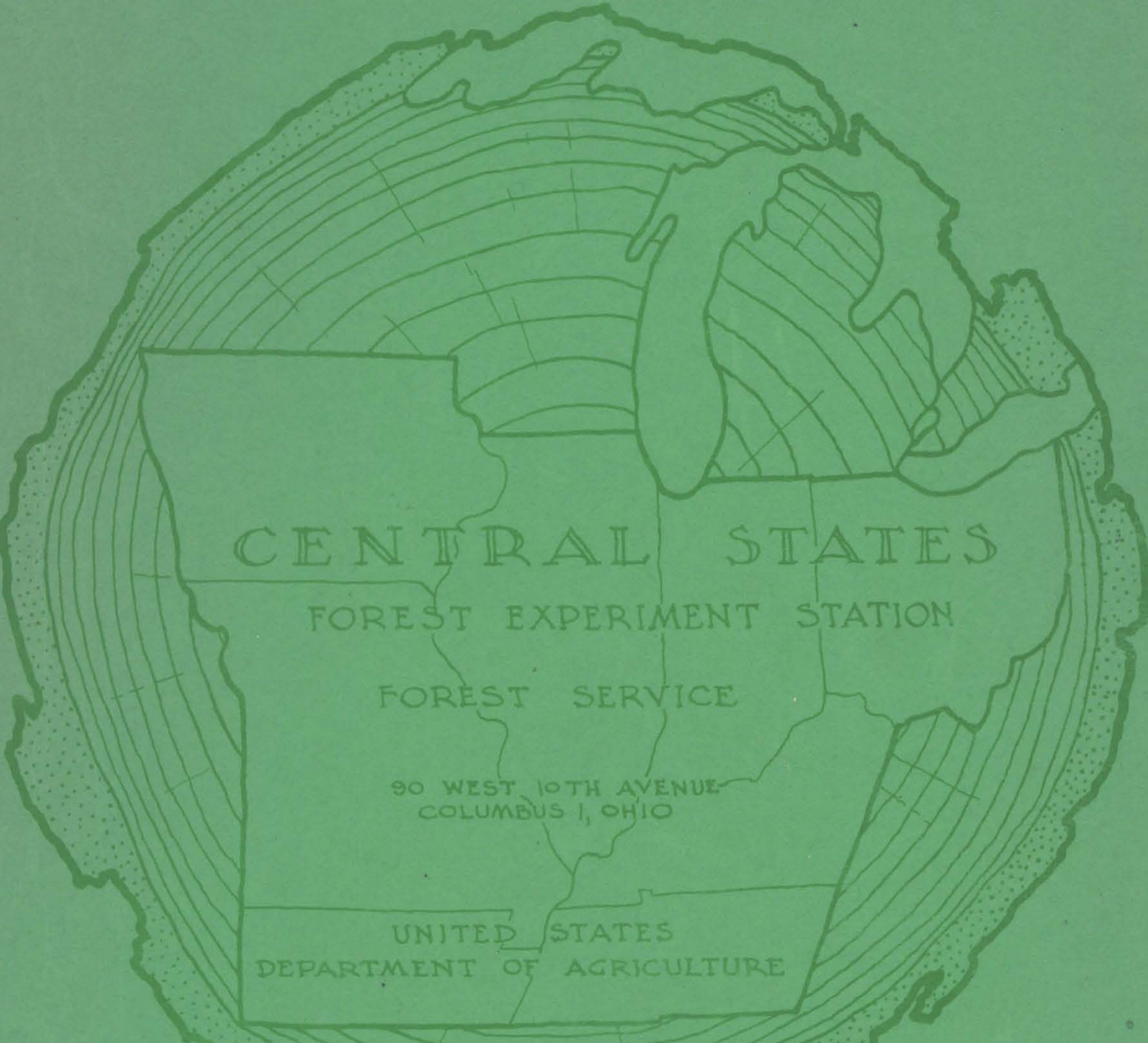

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CENTRAL STATES FOREST EXPERIMENT STATION
~~FLOOD CONTROL SURVEYS~~

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PUBLICATIONS
Technical Paper 104

90 West Tenth Avenue
Columbus 1, Ohio

January 31, 1945

Director, Intermountain Forest
and Range Experiment Station
Ogden, Utah

Dear Sir:

The problems presented by strip mine spoil banks are receiving much current attention in the Central States. Although reforestation is generally conceded to be a promising method of making these areas productive, the spoil banks present one of the most difficult planting problems which confront foresters in the region.

Technical Paper 104 outlines progress in spoil bank reforestation research by the Central States Forest Experiment Station. While based on experiments established in Ohio, the type of spoils investigated is fairly common over the Central Region and the results should be of interest and use in managing similar spoils in other states.

We trust you will find the enclosure of interest and will be glad to have any comments or suggestions you might care to make. A few extra copies are available and will be mailed upon request.

Very truly yours,

Leonard I. Barrett

LEONARD I. BARRETT
Director

Enclosure

FOREST PLANTING ON STRIP-MINED COAL LANDS WITH SPECIAL REFERENCE TO OHIO

By

A. G. Chapman
Chief, Division of Forest Management Research
Central States Forest Experiment Station

INTRODUCTION

The commercial development of strip- or open-cut coal mining in the Central States of Ohio, Kentucky, Indiana, Illinois, Missouri, Kansas, and Iowa during the last thirty to thirty-five years has been accompanied by the problem of vegetating the resulting spoil banks. The present extent of the problem area for the region has been estimated at approximately 110,000 acres of land actually stripped. Undisturbed surfaces within mined tracts which generally increase in percentage with increase in relief of the land are not included in this acreage. For example, in hilly eastern Ohio undisturbed surfaces average about 75 percent of areas mined, whereas in southwestern Missouri and eastern Kansas only about 10 percent remains undisturbed where the terrain is undulating to gently rolling. Reliable estimates of the area which will ultimately be stripped in the region are difficult to make, but geologists and others have indicated that in the eastern portion of the region one-third to one-half of the strippable coal land has already been mined and that in the western portion only one-tenth has been mined. It is possible that the ultimate area stripped for coal only will approach a million acres. In addition, but on a much smaller scale, there will be somewhat similar spoils resulting from strip-mining of clay, iron ore and limestone.

The extent and rate to which this type of coal production develops depend upon the economics of the operation as related to such factors as depth and character of overburden, depth and quality of coal seam, development of methods and machinery, and the demand and price of coal. As recently as 15 years ago, 30 feet of overburden was near the maximum which could be economically removed, but the development of electric shovels in the last few years, with bucket capacities of 35 or more cubic yards, has made possible the economic removal of as much as 85 feet of soil and rock overburden. New types of earth-moving equipment, being tested by the

industry, may result in removal of still greater depths of overburden in the future. On an average it is estimated that with existing equipment about 15 feet of overburden can be removed for each foot of coal. With each increase of state or national requirement for coal and its consequent higher prices comes stimulation of stripping. The first noticeable major increase in production began in 1917, reaching a peak for Ohio of over three and one-half million tons in 16 counties in 1920. Production then declined to a low of about 800,000 tons in 1932 and did not again reach the 1920 level until 1939, when it amounted to almost 4 million tons. Other unforeseen improvements in methods of production, changes in the relative costs of strip and shaft mining and other factors may further extend the present calculated economically strippable areas.

Although the acreages stripped do not represent high percentages of the land of the Central States or of individual counties, nor highly valuable agricultural lands in most instances, the mining does liquidate the usual agricultural resource which is often important in the economic balance and stability of the local communities. Liquidation is primarily due to the newly created sharp relief, but in addition there are the raw, unweathered rock materials which produce problems not encountered in revegetation of old fields. Together the rugged relief and bank materials on stripped land originate a far greater and more difficult reclamation job than an equal area of the average land retired from agriculture. Too, the general devastated appearance of spoils may lower the value of adjacent unstripped land. Many owners of stripped lands recognize an obligation and have taken steps to make them productive of natural resources. For the most part these efforts are evidenced in action taken to forest the spoil banks.

Beginning as early as 1920, some tree planting, much of which is unsuccessful, was done on spoils in every state of the region. In contrast to the lands abandoned from agriculture which comprise the largest reforestation areas, spoil banks probably present the most difficult problems. They present sites for which there are few if any parallels found under natural conditions so that revegetation efforts have comparatively little precedent after which to pattern. Revegetation of these areas by natural development is comparatively slow in most cases. Without improved management programs, the raw banks will constitute in the future the least useful and most unproductive class

of land in the Central Region. In view of the abnormal difficulties of the problem and the possibility that a million acres may eventually be stripped, early attention must be given to research that will develop successful methods of forestation.

Although the following discussion on spoils and on efforts by different agencies to establish forest covers on them specifically relates to Ohio, many of the principles involved and recommendations offered may apply equally well to other strip-mined areas of the region. The portion of Ohio affected by strip-mining operations in the last 31 years comprises 26 eastern and southeastern counties, 15 of which contain from 90 to 95 percent of all the stripped land in the state (Fig. 1). To date the overburden has been removed from approximately 17,800 acres[1/]. Because the moving of overburden commonly requires that some of it be piled on adjacent unmined land, the total area of spoils is somewhat greater than this. Additional areas, unmined but retired from former use because they have been rendered inaccessible by the creation of spoil banks add still further to the area affected. Therefore, in addition to the area actually stripped, there is an unknown acreage that is affected by this form of mining and the whole constitutes the land use problem resulting from this kind of mining.

The spoil banks offer opportunity for reclamation for a variety of uses such as forestry, pasture, nut and fruit crops, wild life and recreation. However, the major purpose of this paper is to present a basic classification of spoils for forestation purposes, to outline results of current research by the Central States Forest Experiment Station in forest planting of banks of sandstone and shale spoils, and point to the needs for further planting research.[2/]

1/ Calculated from production figures in annual reports of the Ohio Department of Industrial Relations using average of 5,000 tons of coal per acre stripped.

2/ This paper deals with the vegetation problems only of spoil banks. But, as already pointed out, the whole mined tract is a land use problem, and, therefore, reforestation of unmined "islands" within such a tract should be considered simultaneously with forestation of the spoils.

CLASSIFICATION OF SPOILS FOR FORESTATION

Spoils Groups by Kinds of Overburden

The spoil banks of the strip-mining area of Ohio have been divided into three groups based upon differences in kinds of materials or formations above the coal seams. Distribution of these groups is shown in Figure 1. For convenience, the groups are designated as 1, 2, and 3.

Group 1 spoils are typical for those counties and portions of counties above the line of glaciation where mostly mining of numbers 4, 5, and 6 coal seams[3/] occurs (number 6 being most important).[4/] In this glaciated area, the overburden is primarily composed of noncalcareous till and residual sandstones and acid silt shales. Much of the till in the unmined land is 20 to 30 feet deep, and often has a greater depth than the underlying residual sandstones and shales.

In the mining process, the residual rock is dumped on top of the spoils; but the proportion of the entire spoils which it comprises is neither great enough to cover the glacial material nor to make necessary a long-time weathering period before planting. From inspection it appears that a few months of settling may be adequate to render these banks plantable.

Group 2 spoils include those of unglaciated counties where sandstones and acid silt shales form most of the overburden removed in mining of numbers 5 and 6 coal seams. The depth of the soil profile overlying these rock strata usually ranges from 3 to 6 feet which, except when shallow cuts are made, contributes disintegrated, weathered materials, amounting to about 10 percent of the spoils. This is mostly covered in the banks with rock.

Sandstones and shales are least resistant to weathering of the rocks encountered in stripping. Near the unmined surface these are already partially weathered, a condition which later hastens disintegration and settling in the banks, and is especially important in shallow cuts. The larger exposed rocks in these banks

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3/ Stout, Wilbur. 1939. General section of coal-bearing rocks of Ohio. Geol. Sur. of Ohio, Cir. No. 2, Fourth Series.

4/ Coal seams are numbered in the "coal measures" from the bottom to top.

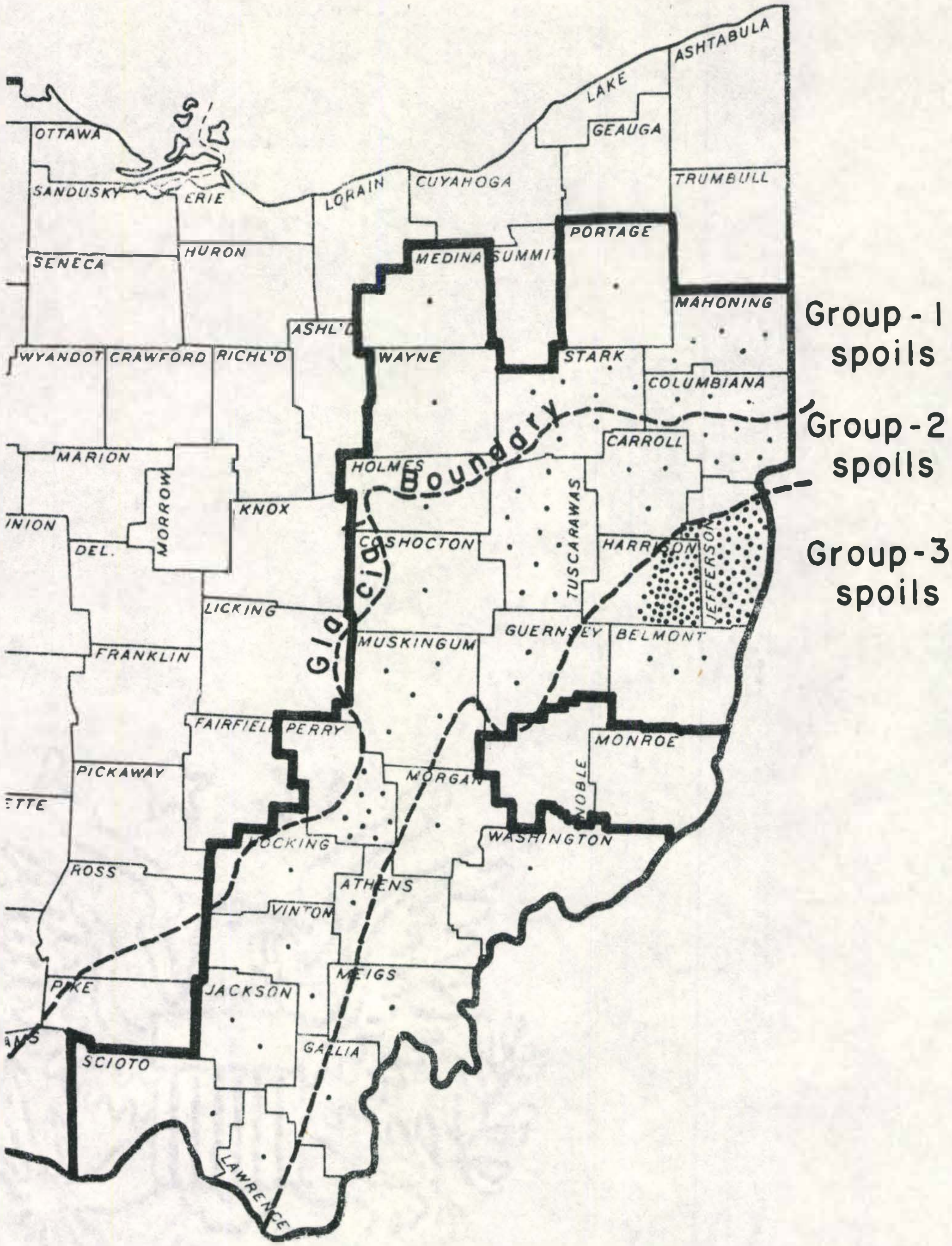

Fig. 1. Counties of eastern Ohio for which Ohio Department of Industrial Relations has reported strip coal mine production. Broken lines separate the section into three recognized groups of spoils. Each dot represents 100 acres of stripped land.

break up in 5 to 10 years. Although there are occasional exceptions, enough finer materials are usually present to make long waiting periods for disintegration unnecessary. The resulting spoils have low clay content and, after several years of decomposing and settling, the materials are still friable and have excellent water-holding capacity and aeration. These characteristics generally indicate successful reforestation possibilities.

The proportion of rock in Group 2 spoils, as well as in other groups, varies directly with the relation of soil depth to depth of cut. In the area of these spoils, depth of stripping usually does not exceed 35 to 40 feet. The smaller masses of materials resulting from this relatively shallow mining, quite comparable in depth to that in the Group 1 area, disintegrate and become compacted sooner than spoils from deeper overburdens.

Group 3 spoils are those of the unglaciated counties where the overburden of the number 8 coal seam (and number 8a to a limited extent) is comprised of sandstones, marly clay shales, and limestones in addition to the material from the soil profile. Percentages of the calcareous shales and limestones are great enough to produce a highly calcareous spoils. Quantities of clay and clay-forming shales are sufficiently great in many places to effect a tight, impervious, poorly aerated material upon disintegration and settling.

The limestone of this overburden is hard and far more resistant to weathering than the sandstones and shales. This and the generally coarser rocks left by blasting cause banks to persist in a virtually unchanged condition far longer than those of Group 2.

Although there is shallow stripping within this spoils group area, the deepest strip-mining in the state occurs here. This is caused by the greater relief and the higher quality coal in the number 8 seam. A 60-foot cut is commonly made and occasionally an overburden 85 feet in thickness is removed. Consequently, excepting the outside banks, the spoils have an insignificant proportion of fine materials from the shallow soil profile.

Significance of Spoils Characteristics in Forestation

The spoils classification outlined above is based largely on the distinct geologic formations from which each

group is derived. Although not yet confirmed by research results, the classification also represents site characteristics which experience indicates will be reflected in differences in species that will do well, survival and growth of seedlings, and the period required for settling and weathering. There will be variations within each group, but the complex of characteristics of any group makes it distinct enough to justify recognizing it as such. In general, it is believed that Group 1 spoils can be planted the soonest after stripping. First, the banks, largely of glacial till, settle enough in a few months to warrant planting within a year after stripping. This differentiates them from others as the group offering the fewest problems to early reclamation. Second, uniformity of composition and texture of the glacial till is more conducive to greater and more uniform survival and growth than spoils of higher residual rock content. And third, a higher level of fertility in these spoils may be expected because soil nutrients are more readily available in the glacial till. This assumption is based partly on the fact that unmined farm lands in this glaciation are more productive of agricultural crops than the unglaciated lands to the south.

Group 2 spoils rank second in ease of reclamation which may begin in 1 to 5 years. The sandstones and shales weather readily, the process being enhanced by the normally high quantities of pulverized rock in this overburden resulting from blasting and stripping. Much variation in spoils texture, associated mostly with depth of mining, is found in this group. Planting of spoils which result from the deeper stripping and consequently have the greater quantity of the harder unweathered rock, should be delayed longer. Spoils of this group, low in clay and clay-forming rock, remain friable and have excellent water-holding capacity and aeration even after several years of disintegration and settling. These characteristics make them comparatively favorable planting sites from a "soils" viewpoint in spite of their relatively low mineral nutrient content.

Group 3 spoils, although richest of the three groups in mineral elements, promise to present the most difficult problems. The presence of large quantities of limestone in many of these banks will require a longer weathering period and make the job of planting more difficult. Some banks, however, contain sufficient proportions of clay layers, marly shales, and sandstones, all of which disintegrate rapidly, to render

them plantable in two or three years. The clays and marly shales, also clay-forming, usually comprise much of the first plantable "soils" of most banks of this group. These eventually compact into an impervious, poorly aerated spoils quite unfavorable to both survival and growth of planted trees.

The calcareous rocks of Group 3 are among the richest in the mineral elements essential for tree growth. Upon the addition of nitrogen either through artificial application or nitrogen-fixing organisms to these materials when disintegrated, they develop into excellent "soils" for plant growth, provided their physical conditions favor adequate moisture and air.

Some forest tree species are known to react differently to calcareous "soils" than to noncalcareous ones, but their requirements have been not so well defined as those for agricultural plants. Hardwoods seem to be somewhat less sensitive to soil lime-content variations but some species, as black walnut, yellow oak, blue ash, Kentucky coffee tree, and a few others occur more commonly on calcareous soils and seem to develop better there. Although black locust has been reported to develop better on limestone-derived soils, equally as good stands have been found on sandstone and acid shale soils. Pine species are usually confined in their natural distribution to noncalcareous soils or at least to acid soils, seedlings of some being unable to survive the early germination periods in calcareous ones. These differences in requirements of various species indicate that the species most suitable to each group of spoils may differ and must be determined by systematic test.

Toxic materials in the spoils sometimes inhibit plant growth until sufficient time has elapsed for their removal through leaching. Most common of these in spoils is iron pyrite which oxidizes upon weathering to ferrous sulphate. In Ohio it occurs chiefly in the coal bed, and in the stripping process is often dumped on the top of banks, however, not uniformly nor in great quantities. Such conditions are more likely to be troublesome in Groups 1 and 2 banks and have to be avoided until sufficient leaching has taken place. In the strip-mining section of southwestern Indiana these iron-sulphur compounds occur not only in or near the coal vein but in great quantities in lenses of shales often 3 to 4 feet thick, several feet above the coal vein. Such high acidity obtains that vegetation

cannot exist in small spots which total about 10 percent of most stripped areas. The remainder of these Indiana spoils have pH values varying from 4.5 to 7.5, a range of tolerance for most plants.

To be considered plantable, spoil banks must have at least a sufficient quantity of soil materials with a water-holding capacity in the seedling root zone adequate to support seedling plants through the dry periods of summer. This condition can generally be detected by inspection during the drier summer months. It is estimated that as much as 80 to 90 percent of Group 1 spoils is plantable within one year, 50 to 60 percent of Group 2 spoils within 2 to 3 years, and approximately 50 percent of Group 3 spoils in 8 to 10 years. Many spoils may be considered plantable although as high as 10 percent of their area may be too acid for tree growth. The toxicity occurs in relatively small spots which are usually widely distributed. These spots may be avoided or disregarded in the planting process if an adequate cover can be anticipated. Fertility varies much among the spoils; but the lowest level, in otherwise plantable banks, is not sufficient to render planting a failure. Nitrogen is undoubtedly the most deficient essential element but not often entirely limiting. It can be supplied through use of legumes, or artificially when non-legumes are used in cover establishment.

RESULTS OF PLANTING RESEARCH ON GROUP 2 SPOILS

In 1937 a series of formal planting studies on spoil banks of Group 2 was begun by the Central States Forest Experiment Station and continued through 1940 on the Kehota Area, Perry County, Ohio, to explore the possibilities of establishing a forest cover. The banks were 7 years old when planted. How much sooner these banks could have been successfully planted is not known but indications from conditions of more recent spoils in the vicinity point to possible successful cover establishment in 1 to 2 years. The area involved in the investigations comprises about 100 acres generally representative of Group 2 spoils.

Almost no natural plant reproduction had developed during the 7 years intervening from stripping to the planting. Figure 2 shows the bareness of the spoils in 1937. Besides a few small clumps of black locust near the bases of bank slopes, apparently having developed from root segments shortly after the operation,

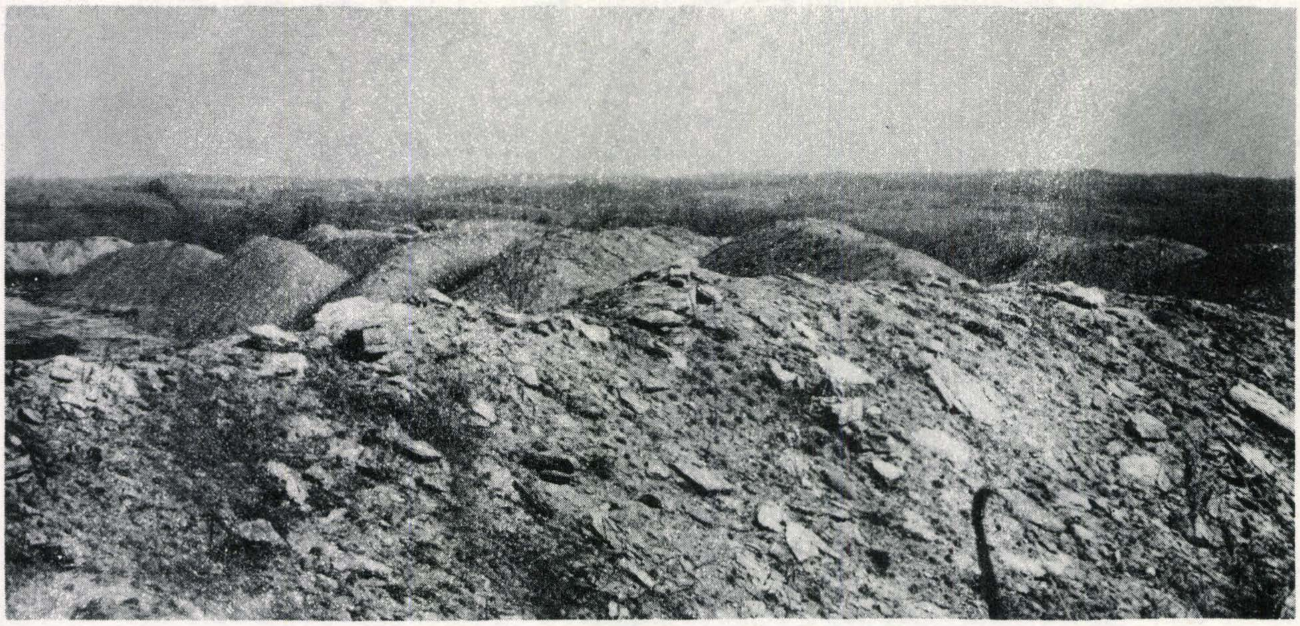

Fig. 2. Raw condition of seven-year-old group 2 spoils on Kehota area, Perry County, photographed in spring of 1937 at time experimental plantings were begun.

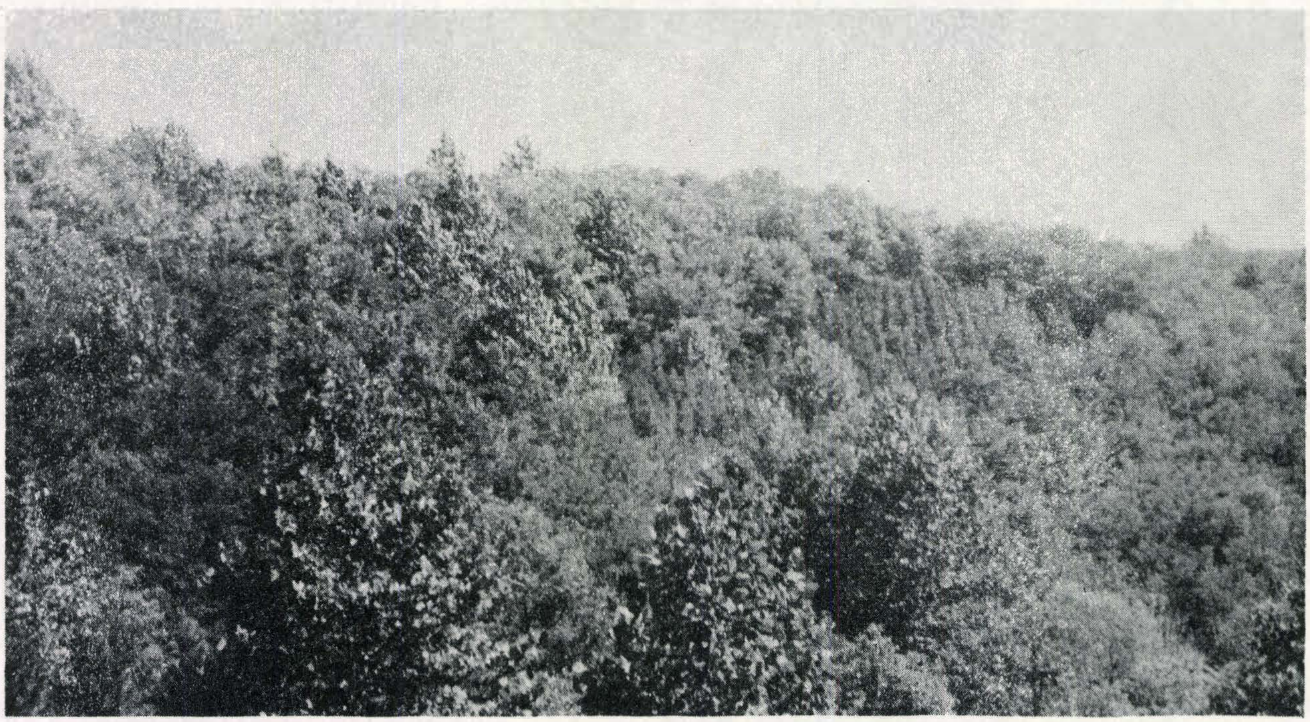

Fig. 3. The same banks shown in Figure 2, from a slightly different camera point, photographed in summer of 1944 seven years after planting. Scattered cottonwood and sycamore trees were about five-foot seedlings at time locust was planted.

there was a small number of "whip-sized" sycamore, cottonwood, and aspen seedlings present. These latter light-seeded species generally make up any pioneer tree cover on such areas, generating from large numbers of wind-blown seed. Figure 3 represents the same banks 7 years after planting from a more distant camera point.

Some of the outside banks received many natural crops of yellow poplar, hard maple, elm and white ash seed. However, no seedlings of these species could be found when planting began. The extremely high temperatures developing during the late spring and summer months in the rock particles on the bank surfaces inhibit germination and survival of seedlings of these and other species. The droughty condition of 2 to 3 inches of the surface spoils also is equally lethal to young seedlings. Another destructive factor is the sloughing effects produced by alternate freezing and thawing during the winter and early spring. In this area, the effect has been more pronounced on north exposures than on south. Severe erosion during heavy rains is responsible for further loss. Young seedlings with shallow roots, growing from seed in place, are particularly susceptible to these factors.

In the 4-year period, 1937 - 1940, some of the most likely species for establishing a forest cover were tried in the test plantings. The use of black locust and shortleaf and pitch pines in establishing covers on old-field areas with and without ground cover led to the employment of these species also on the spoils. The high amount of available moisture and good aeration in the banks apparent at planted root depths led to the use of yellow poplar, green ash, and northern red oak in the experiments. Natural reproduction of cottonwood and sycamore on older banks prompted their use. To these silver maple was added because of its rapid growth rate under favorable conditions.

All of the investigations involved replicate random plots. The basis for the general evaluation of these plantings are the analyses of survival and growth observations. Neither field design nor statistical treatment of data will be discussed here.

To achieve quick stabilization of banks and creation of an early semblance of soil conditions, it is necessary that a species develop rapidly; hence, selections also should be made for planting with this in mind. Survival alone without rapid growth is not enough because

slow growth does not permit early and adequate root anchorages on a surface constantly shifting from weather action.

Tests of Conifers

1. Relative responses of 1- 0 and 2 - 0 shortleaf and pitch pines. In the spring of 1937, one- and two-year-old seedlings of both shortleaf and pitch pines were planted on north and south aspects of Group 2 spoil banks as the first of a series of cover establishment tests. In general the planting stock was small, as indicated by the following seedling top height ranges in inches:

Age	Pitch pine Inches	Shortleaf pine Inches
1 - 0	3.5 - 5.0	4.5 - 5.5
2 - 0	4.5 - 5.5	5.0 - 6.5

Improved nursery practices have since made it possible to develop much larger, sturdier, and better-balanced stock for both species which should prove better for bank use.

Table 1 indicates that there are no practical differences for either species with respect to stock age or aspect although results somewhat favor shortleaf pine. The stock classes for both species gave quite satisfactory survival and growth on the two aspects tested in this spring planting.

Table 1.--Mean heights in feet and survival percents by species, age classes, and aspects and total mean heights and survivals after 8 years in plantation.

Aspect		Pitch pine		Shortleaf pine	
		1-0	2-0	1-0	2-0
North	Ht. in feet	8.3	10.1	9.7	9.8
	Sur.percent	84.4	87.5	95.3	93.8
South	Ht. in feet	10.0	9.6	12.2	10.9
	Sur.percent	83.3	93.7	90.6	88.6
Total	Ave. Ht.	9.0	9.8	10.6	10.3
	Sur.percent	83.9	90.2	93.7	92.0

Equally as important as satisfactory survival and rapid early growth is the conditioning of the spoils and ameliorating of atmospheric conditions within the planting to better favor natural seedling reproduction of hardwoods. Figure 4 shows litter conditions and ground vegetation as developed in the 8-year-old shortleaf stand. Litter to date is very light, and herbaceous and other ground cover plants are only slightly more advanced than on unplanted banks. These are generally better developed on north slopes than on south. The chief species, wild oat grass, common cinquefoil, goldenrod and others, are indicative of dry soils, low in fertility. The soil surface temperature and moisture still fluctuate widely, representing, however, less severe conditions than those of unplanted banks.

2. Shortleaf stock age classes in fall and spring plantings. Plantings of 1 - 0, 2 - 0, and 1 - 1 shortleaf pine stock were made in the fall of 1937 and spring of 1938 to test further the response of stock classes but more particularly the effects of planting season. Top lengths of the 1 - 0 seedlings ranged between 4 and 8 inches. Since the 2 - 0 and 1 - 1 stock had been pruned in the nursery beds during mid-growing season the previous year, their tops were more uniformly about 8 inches in length.

Of the factors under test, only the effect of season of planting developed as having significant influence on survival and growth. Similar to the results obtained in test 1, different responses by stock age classes, which obtained in the first two or three growing seasons, failed to persist after 7 years. However, as shown in Table 2, the effect of season upon survival and growth, with spring planting excelling fall planting, has much significance in establishing a tree cover on spoils. The results from fall planting on these spoils are somewhat worse than those of similar experiments on old fields, probably because of the greater bareness and less firm "soil." The outcome is quite typical of most fall plantings on eroded areas unprotected by mulch or ground cover during the winter months. Loss from winter killing and frost heaving was somewhat greater on north than on south slopes, but not enough to justify any added cost for different treatment in plantihg.

Table 2.--Effects of season of planting on survival and height growth of shortleaf pine 7 years after planting.

Mean Values	Planted Fall 1937	Planted Spring 1938
Height in feet	8.6	11.0
Survival in percent	38.6	95.0

Figure 5 represents a portion of the 1938 spring-planted stand sampled for the measurements in Table 2. Although crowns are closing, in most of this planting, not enough litter or ground vegetation has yet developed to sufficiently stabilize surface materials for favorable seed beds.

Pitch and shortleaf pines, in spite of their somewhat better growth on spoil banks than on nearby old fields, do not stabilize spoil bank surfaces quickly and hence do not favor immediate natural regeneration of hardwood species. If early natural restoration of native hardwoods is an objective, this slowness of pitch and shortleaf pines to effect soil stabilization is a disadvantage; but if not, then they may well be recommended for spring planting on sandstone and acid shales of Group 2 spoils.

3. Eastern red cedar. In the spring of 1938, 1- 0 red cedar seedlings with top lengths from 2 - 4 inches were included among species tested on the Kehota spoils. The stock was considered somewhat small, but larger stock was not available. However, after 7 growing seasons, 85 percent of the planted trees are in thrifty condition. Growth has been erratic and unsatisfactory as regards stabilization and improvement of the spoils. Heights range at present from 1 to 6 feet, averaging about 3 feet. Of particular interest is the occurrence of the best growth, 4 to 6 feet, at one side of the plot which was unintentionally overlapped with a locust planting in 1939. Whether the better cedar growth is a response to the overtopping locust or merely coincidental may be determined in later formal tests. The same kind of stock planted in adjacent old-field plots at the same time now average about 8 feet in height, definitely representing better growth.

Fig. 4. Very light litter and ground cover of dry site species under seven-year-old planting of shortleaf pine, typical of bank surfaces under this age of shortleaf and pitch pine plantings.

Fig. 5. Shortleaf pine planted in spring of 1938 and source of data in last column of Table 2. Measure in foreground is five and one-half feet.

Tests with Hardwoods

1. Hybrid poplars, cottonwood, sycamore, silver maple, red oak, green ash, yellow poplar, and black locust. The only complete failures among these hardwoods resulted from attempts to establish hybrid poplars (*Populus* sp.) and cottonwood by means of cuttings. Stratified cuttings of 25 hybrids were used in a series of plantings in the spring of 1939. At the end of the first growing season, 67 percent of the cuttings were still living but not one had exceeded 2.3 feet in height growth. Survival at present, 6 years after establishment, is approximately 30 percent. There has been much seasonal dying of the poorly formed, branchy tops, none of which exceeds 5 feet in height. Another series of plantings was made with stratified cuttings of local cottonwood in 1940 with the same general failure. In spite of these failures, there are two indications that some degree of success may still be forthcoming in these Group 2 spoils after further research. First, scattered natural regeneration of native local poplar species is growing well; and second, cottonwood cuttings were used in establishing the plantings on the Jefferson Company Group 3 spoils in Harrison County. Differences in spoil materials may have been the cause of the different results. Use of seedling stock might prove more effective than cuttings in establishing such plantings.

Table 3 gives the year of spring planting, the 1944 survival and height attained since planting of 1 - 0 stock of sycamore, silver maple, red oak, green ash, and yellow poplar. Survival is quite acceptable for all species except yellow poplar, but the growth rate of these hardwoods is unsatisfactory for establishment of an early cover.

Table 3.--Present mean survival and height of 5 hardwood species planted on Group 2 spoils.

Species	Date of Planting	Mean survival & height: Survival	Mean survival & height: Mean height and height range	Growth Period
		Percent	Feet	Years
Sycamore	1940	96.0	3.5 (2.2 to 5.2)	5
Silver maple	"	98.0	3.3 (2.6 to 4.0)	5
Red oak	1938	94.5	* -	7
Green ash	"	98.1	2.7 (0.7 to 7.0)	7
Yellow poplar	"	67.1	2.6 (0.4 to 6.8)	7

*Heights not measured but average estimated at not over 3 feet.

Figures 6 and 7 represent portions of the 7-year-old green ash and yellow poplar plantings on north slopes. These may persist long enough to result eventually in acceptable plantings, but lack the capacity under Group 2 spoils conditions to develop an effective cover within a reasonable time. The sparse vegetation of dry-site species on the ash plot (Fig. 6) represents the maximum cover observed on exposed slopes since stripping. Washing and sloughing are still enough to keep some roots of many of the planted trees exposed, greatly retarding their growth. The gullied, bare surface in the yellow poplar planting is the more common situation.

2. Black locust. Black locust was first included in the series of experimental plantings on spoils in the spring of 1938. The fact that approximately half of the planted seedlings attained a height of 5 to 9 feet the first season gave promise of an effective cover. Table 4 contains a summary of measurements on these plots after 7 years. Diameters at 4.5 feet are given by crown classes since differentiation of crowns has been in progress for 3 or 4 years resulting in suppression of the less thrifty trees and in natural thinning.

Table 4.--1944 classification of black locust on 1938 experimental plots by crown and d.b.h. classes.

Mean values	Crown classes: Dom.	Codom.	Int.	Overtopped
D.B.H. in inches	3.1	2.4	1.9	1.4
Percent of stand	19.5	26.0	24.0	30.5

The present survival based on the number of planted trees is 78 percent of the original as against 98 percent at the end of the first growing season. The rather sharp drop in the 7 years is due almost entirely to the natural thinning processes. The average height of trees in the dominant and codominant classes is approximately 25 feet. Trees of the intermediate and overtopped classes are unlikely to survive the increasing competition with the more vigorously growing ones.

LARGE-SCALE LOCUST PLANTING ON WAYNE NATIONAL FOREST

In 1939 and 1940, the Wayne National Forest planted approximately 100 acres of Group 2 spoil banks on the Kehota area chiefly to black locust. Figure 8 repre-

Fig. 6. Seven-year-old green ash on north facing slope of Kehota spoils. Data for this planting are given in Table 3.

Fig. 7. Seven-year-old yellow poplar planting on north facing slope of Kehota spoils. Bank is still bare and gullied here but stabilized under locust on left planted two years later.

sents a portion of the 1939 planting, whose dominant trees have already attained 25 feet in height, a typical response of the species under these Group 2 spoils conditions. A mean survival of 88 percent is indicated from sample plots on the area. Of the present trees, or 1,066 per acre, 62.7 percent (668 trees per acre) are in the dominant and codominant classes. The breakdown of trees in the stand by crown classes and d.b.h. classes is shown in Table 5. It is believed that a high percentage of the dominant and codominant trees will grow to post size in the next 6 to 8 years.

Table 5.--Classification of black locust trees on sample tenth-acre plots in 1939 plantings by crown classes with their mean d.b.h. values.

Mean values	Crown classes: Dom.	Codom.	Int.	Overtopped
D.B.H. in inches	2.9	2.3	1.8	1.3
Percent of stand	33.3	29.4	19.8	17.5

It may well be assumed that most posts produced will come from these two larger crown classes. Although a few trees with d.b.h. values of 3.5 to 3.8 inches are already within the range of small post sizes, no reliable estimate may yet be made of the percentage of trees in this stand which will yield posts or the average number of posts per tree. However, the possibilities are good for profitable yields.

Quite unlike the bare, eroded appearance of the ground surface in the pine and other hardwood plantings, the bank surface beneath the locust (Fig. 9) has at least a 2-inch litter. Only the narrow ridge crests and other small areas under the locust that are exposed to sweeping air currents have light, ineffective litter deposits. Besides stabilizing the bank surface and modifying the highly fluctuating soil moisture and temperature[5] of the bare surface, the litter effects the beginning of soil formation. In this stand, an abundance of nitrogen-fixing nodules on the network of fibrous roots is present near the surface of the mineral materials. These contribute greatly to nitrogen supply most needed to stimulate plant growth in the spoils.

5/ On June 21, 1944, midday "soil" surface temperatures just beneath the litter and on an adjacent bare area were, respectively, 85° F. and 123° F.

A small portion of the Kehota spoils, resulting from stripping about 1920, was planted with black locust either by the coal company or the land owner a few years later. Borings indicate this stand (Fig. 10) is now 18 years old with from 180 to 200 trees per acre of merchantable post size. Diameters of the trees at 4.5 feet range from 4.5 inches to 9 inches, radial increment being 4 to 6 annual rings per inch. Merchantable heights vary from two to five 7-foot post lengths with an estimated average of three and one-half lengths per tree. Assuming 180 trees per acre with an average of three and one-half posts per tree, a production of 630 posts per acre in 18 years results.

A luxuriant growth of herbs, shrubs, and hardwood reproduction has developed as an understory. Already an adequate stocking of yellow poplar, white ash, elm, and other tree species is established and growing vigorously. About two and one-half inches of litter have ameliorated soil factors to the extent of creating excellent conditions for growth. Also throughout the upper 2 inches of this "soil," an abundance of locust root nodules occurs.

OBSERVATIONS ON PLANTINGS ON GROUP 3 SPOILS

Only during the last 8 to 10 years has forest planting of spoil banks received much attention in the State. Prior to this period a few plantings of small size were made, most of them being in Harrison and Jefferson counties in Group 3 spoils. The majority of these older plantings have been described as failures by those acquainted with them, particular emphasis being placed upon the failure of black locust, the species most commonly used. It has been indicated that early growth, up to 10 years, was quite satisfactory, followed by rapid decadence.

Recent examinations of the bank materials, in which some of these older locust plantings have failed, strongly indicated the cause of stand deterioration. The plantings in the vicinity of Cadiz and Hopedale, Ohio, were made on banks containing much tight clay, previously described as characteristic of Group 3 spoils. Limited root penetration and low available water-holding capacity of the tight colloidal materials render the trees subject to damage by even short droughts. The most probable explanation of the high mortality is that the water requirements of the stands

Fig. 8. Six-year-old black locust on east facing slope of Kehota spoils. Data for this planting are given in Table 5.

Fig. 9. A 2-inch litter accumulated beneath the six-year-old locust planting represented in Figure 8.

as they develop exceed the available moisture-supplying capacity in the zone of root penetration. Poor aeration in the spoils about the root is certainly another factor contributing to the decadence.

One- to three-year-old plantings of locust in Harrison and Jefferson Counties by the Ohio Reclamation Committee show vigorous growth on 3-year-old banks. These plantings may become decadent as did the older ones and serve only as nurse crops for associated hardwoods planted with the locust. This use of locust alone on these spoils, if effective, would fully justify the locust planting cost. However, research to test locust responses in Group 3 spoils (1) to different conditions in the variable bank materials and (2) to time of planting with respect to age of spoils may help describe conditions where the species will further develop into merchantable products. Planting these banks before they undergo thorough settling may be a partial solution of the difficulty.

Locust borer attacks have been destructive in the older plantings of Group 3 spoils, and are believed to have been much stimulated because of the loss of tree vigor attributable to unfavorable "soil" conditions. Many small stands of natural locust now of merchantable size, on undisturbed slopes below the coal deposits show much less borer damage. More recent plantings of white ash, northern red oak, yellow poplar, and cottonwood, near Bloomingdale, Jefferson County, made on the Jefferson Company land in 1938 on about 20-year-old banks are generally promising. Although stagnation may develop later, no evidence of it is yet present. The following are approximate heights of the 7-year-old stands:

Species	Mean Height	Range of Heights
White ash	10	8 to 15
Red oak	8	3 to 12
Yellow poplar	5	2 to 6
Cottonwood	35	25 to 40

Species of pine, red, white, and pitch, in 1-, 2-, and 3-year-old plantings on 3-year-old banks in Harrison County have survived well, but have grown slowly in contrast to the rapid growth of adjacent locust plantings of the same age. No stabilizing effect by the pines on the bank surfaces is yet in evidence as it is

by the locust. From recent observations on plantings on the 3 groups of spoils considered, also from the relative extent of stripped area involved, it is apparent that Group 3 spoils are in greatest need of research attention.

THE FUNCTION OF BLACK LOCUST ON GROUP 2 SPOILS

The functions which can be performed by black locust if properly planted on spoil banks are (1) development of better site conditions for natural or planted hardwood seedlings of other species which cannot survive or do well under bare spoil bank conditions, and (2) production of fence posts and other products. Both of these functions may be realized from plantings on sites most favorable to growth of the species. Only the first may be performed on the poorer sites. Here locust serves primarily as a nurse crop. If planted to proper density locust will afford protection against drying winds and high fluctuations of temperature near the ground surface, deposit sufficient litter to reduce evaporation to a minimum at the "soil" surface, add organic matter to the spoils, aid in stabilizing the bank surface, and develop a network of nodule-forming roots to supply the much-needed nitrogen. Accomplishment of these things will improve site conditions sufficiently so that native hardwoods can be established by planting or naturally if seed sources are present. A tree spacing not greater than 7 by 7 feet is required to obtain the desired effects. All these have already been accomplished in the stands represented in Figures 8 and 10. Their combined effectiveness is evidenced by the vigorously growing natural reproduction of hardwoods in these stands where seed sources are available.

Use of Figure 10 does not imply that high-grade post materials may be produced in every planting. It is recognized that planted black locust frequently fails to grow to post quality. However, on Group 2 spoils such as those in the Kehota area, there is much evidence for belief that excellent post stands will develop. In instances of post failure, the cost of locust planting is justified by the site-conditioning function performed.

Fig. 10. An eighteen-year-old locust stand on spoils of the Kehota area, established about eight years after stripping.

SUGGESTED MANAGEMENT OF BLACK LOCUST ON SPOILS

The management of black locust on the spoils of the Kehota area and on similar Group 2 spoils involves (1) producing a nurse cover effective in establishment of natural or planted seedlings of other hardwoods and (2) production of locust posts or other merchantable locust products. In attaining these purposes, it is important to consider the time and manner of introduction of the hardwoods when planting is required and the kind of locust cutting to be done, all of which are advantageous to the natural and planted hardwood reproduction.

Establishment of other hardwoods. A 6-by-6-foot spacing of planted locust seems to be optimum for effectiveness in producing a closed cover in 4 to 6 years. In this period, 1 - 0 seedlings will, with few exceptions, perform the desired functions in qualifying banks for hardwood establishment and growth.

Planting of the desired local hardwoods on banks not subjected to natural seeding may be made in mixture with the locust or later after the locust has become well established. The former has the advantage of requiring only one planting job but the possible disadvantage of whipping-damage to tops by the locust. Such damage generally does not occur under 5 or 6 years following planting. Early locust growth rate greatly exceeds that of other species; consequently, the tops of the other hardwoods are not subject to whipping until the full growth-stimulating effect of the locust is attained. On the better sites, damage may not be experienced because of the continued high growth rate of locust to post sizes. It is doubtful if such top damage should be considered a limiting factor to establishing mixed plantings.

In mixed plantings, it is suggested that 65 to 75 percent of the planting stock should be black locust, the remainder composed of one or more other hardwoods. The composite planting of these species may be accomplished by mixing the proper proportions of the different seedlings in planting boxes or trays, when uniformity of sizes will permit, and instructing planters to use stock without selection. Or by providing planters with separate lots of locust and other hardwood seedlings, a systematic mixture in the row may be easily accomplished. Mixtures by rows, that is 3 to 1 or 2 to 1 of

locust to other species, may be equally simple in establishment and satisfactory in development. Groupwise mixtures seem less desirable since the added stimulus by locust would be in part nullified for trees near the group centers. Of the three suggested methods for mixtures, the one fitting best into the program should be used.

When hardwoods are not planted in mixture with the locust, it is believed advisable to postpone their planting until a few years before or immediately following the first harvesting of locust. Planting prior to harvesting the locust appears the more preferable since a few feet of height growth of the underplanted trees will render them less susceptible to overtopping and suppression by vigorous herbaceous or locust sprout growth that usually develops upon opening of the canopy. Besides likely damage from whipping, underplanted trees whose tops have grown into the locust canopy are more susceptible to injury during the locust harvesting process. Introduction of hardwood seedlings after cutting is not only more difficult because of the tops or lopped branches, but less likely to result in high survival and early growth because of competing vegetation.

Underplanting or after-harvest planting should not require more than 200 to 350 seedlings of hardwoods per acre. These can be more effectively planted in selected spots or openings rather than in any systematic manner.

Method of cutting locust. Selective cutting of the locust stand appears more desirable than clear cutting to accomplish the establishment of a hardwood stand. The residual locust trees then will continue to function in the capacity of a protective cover and of a conditioner of spoils. Planted locust lends itself to selective cutting for posts or other products because of its crown differentiation and the resulting spread of diameters. The first cut may remove most of the dominant trees and some of the codominant trees, leaving for the bulk of the second cut mostly codominant trees and intermediate trees, which recover their growth vigor after opening the stand.

Selection of trees for removal may be made largely on the basis of usable products, but attention should be given to the distribution of the residual trees deemed best for benefit to planted or natural reproduction of

other hardwoods present. Cutting may accordingly result in removal of marginal trees or leaving of some merchantable trees in order to assure favorable growing conditions for the hardwoods whose establishment is of prime importance.

TREND OF RESEARCH NEEDED

Future research on forest planting on strip-mined lands should be particularly stressed on spoils of Groups 1 and 3, with the greater emphasis on the latter because of its greater area and the more critical nature of problems in this group.

For the strip-mining areas in the Central Region as a whole, the first need in developing a forestation research program is an overall analysis of the problem. A major objective of this should be a regional classification of spoils on the basis of characteristics important in forest planting similar to the Spoil Group breakdown presented in this paper. Further, careful analysis would probably show need for more detailed subdivisions than developed here for Ohio. Following this there should be established on each of the significant spoils groups some or all of the experiments described below. The experiments are listed in the proposed order of establishment.

1. Species adaptation tests on older stabilized banks. These would consist of pure plantings of all species considered good possibilities to determine:

   a. The species showing the most favorable combination of rapid growth and high survival.

   b. Those species which show approximately equal growth rates.

These would be considered the most promising for later tests of the best species to use in mixed plantings.

2. Determination of the role of black locust as a nurse crop. These tests should be established concurrently with those in Experiment 1 to determine:

   a. The hardwoods which are actually benefitted by locust in mixed plantings.

b. The spacing and percentage of black locust in mixture with other hardwoods to obtain maximum benefit.

c. Whether the fertilizing of black locust at the time of planting increases its value as a nurse crop sufficiently to justify the practice.

3. Determination of desirable settling and weathering period. Using the most promising species determined from Experiment 1, establish block plantings on banks of various ages to determine:

a. The difference in growth and survival on spoils of varying age.

b. The minimum age at which spoils can be satisfactorily planted.

c. The method of planting most likely to assure good survival.

This experiment should immediately follow the first 2- to 3-year results of Experiment 1.

4. Underplanting of successful black locust plantings with desirable hardwoods. Locust stands established in Experiment 1 should be underplanted to determine:

a. The age of locust stand, beginning probably at 5 years of age, that may be most successfully underplanted.

b. The practicability of direct seeding of hardwoods under locust.

Management studies in established stands should be directed toward meeting the desired purposes, that is, production of posts, pulpwood, mine props and timbers, or saw timber.

SUMMARY

Based on data obtained from the Ohio Department of Industrial Relations, Division of Labor Statistics, it has been estimated that about 18,000 acres of land have been stripped for coal in the State. Under present conditions and methods of stripping, it is indicated that approximately 17,000 to 22,000 acres more in the State are economically strippable by present methods and that in the region as a whole nearly a million acres may eventually be stripped.

Forest planting on spoils in the Central Region began about 1920. A relatively few of the plantings attempted have been considered successful; and a significant proportion of these are only apparent successes since they represent the results of several replantings.

In approaching the solution of the problem of foresting spoil banks, it is suggested that the banks be considered as 3 major groups on the basis of geologic materials in the overburden: Group 1 spoils of glacial till, sandstones, and acid silt shales; Group 2 spoils of sandstones and acid silt shales; and Group 3 spoils of sandstones, marly shales and limestones. Within each group of spoils, other characteristics as proportion of rock present, resistance of rocks to weathering, and composition of rocks, are discussed in relation to time elapsing before being plantable and to choice of species for planting.

In many banks a weathering and settling period is essential for the development of a "soil" sufficiently compact to retain enough moisture for tree survival during the dry seasons and to allow time for the leaching of elements toxic to tree seedlings.

During the first 8 years after planting in Group 2 spoils, shortleaf and pitch pines grow somewhat better than they do in adjacent old fields; but on these spoils, they are surpassed in growth by black locust.

Black locust, which usually stabilizes bank surfaces in 5 to 8 years and deposits a good litter, is much superior to tested species of pine in effecting conditions favorable for early hardwood reproduction as indicated by planted banks subjected in part to seed sources.

Eastern red cedar planting on Group 2 spoils has resulted in acceptable survival; but growth, with the exception of that under locust, is inferior to old-field growth and inadequate for a quick effective cover.

Although good survival was obtained in plantings of yellow poplar, red oak, green ash, silver maple and sycamore on the Kehota spoils, growth rate was too low during 7 years (4 years in case of maple and sycamore) to effect bank stabilization.

For most effective establishment of a hardwood stand on sandstone and acid silt shale spoils, it is recommended that desired species of hardwoods be mixed with locust at time of planting, underplanted in black locust prior to harvesting, or planted in openings at the rate of 200 to 350 per acre immediately after cutting of selected locust trees.

Results from studies on Group 2 spoils of sandstone and acid silt shales in Perry County, Ohio, indicate that 300 to 500 fence posts per acre may be expected from 18-year-old black locust plantings and that some trees reach post size in 8 years.

Observations on unsuccessful plantings of black locust in Group 3 spoils in Harrison and Jefferson Counties in Ohio, where high percentages of clay from marly shales are often found, indicate that under such conditions locust will serve primarily as a nurse crop for other hardwoods.

Information is not available upon which to base a complete grouping of species according to their responses to calcareous and noncalcareous soils. But in instances where such information is available, it should be observed when selecting species for planting.

There is much need for well-planned research, based on composition and physical characteristics of spoil materials, to meet the urgent problem of establishing productive forests on mined areas particularly where Groups 1 and 3 spoils are involved.

Effective methods of meeting the planting problem on spoil areas in Ohio may well apply in principle to solution of similar problems in other Central States.

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